

## **MARKED-UP VERSION OF AMENDED SPECIFICATION PARAGRAPHS**

Please insert the following paragraph at page 1, line 2, before the first paragraph;

### **Cross Reference to Related Patent Applications**

This patent application claims the benefit of U.S. Provisional Patent Application No. 60/118,985, filed on February 8, 1999.

Please replace the paragraph starting at page 1, line 8, with the following:

Large ducted fans are commonly used in the cooling towers of electric utilities to remove heat from the cooling water of heat exchangers. These fans are made up of four to twelve blades which range from 5 to 20 feet (1.5 to 6.1 meters) in length. A standard twelve foot (3.7 meter) blade employing the NACA 63<sub>2</sub> - 615 airfoil from root to tip has been the most commonly used blade in cooling tower applications. This airfoil [is] has a chord thickness of 15% [cord thick], and it is designed for an operating lift coefficient of 0.6 with a low-drag range that extends from a lift coefficient of 0.4 to 0.8. It was initially designed in the early 1940's for use in general aviation and has been in use over the past 50 years. As a result, certain prior art design objectives have evolved over the course of these years.

Please replace the paragraph starting at page 1, line 30, with the following:

The tip airfoil should be thin enough to provide low drag, but should also provide a maximum lift-to-drag ratio (l/d) at high values of lift coefficient to minimize blade solidity. In the hub region, blade-element performance predictions have indicated the presence of low blade angles of attack. As a result, the root airfoil should produce a [lift] high lift coefficient at zero angle of attack. Designing new airfoils, having a minimal sensitivity to roughness, is therefore desirable should the blade operate in a stalled condition. Stalled conditions are usually caused either by an unsteady inflow or the low air density which is encountered when operating the fans at high temperatures.

Please replace the paragraph starting at page 3, line 23, with the following **three** paragraphs:

Figure 1 is a profile of [the] a prior art NACA 63<sub>2</sub>-615 airfoil;[, and the airfoil family according to the present invention.]

Figure 2 is a profile of a tip airfoil according to the present invention; and

Figure 3 is a profile of a root airfoil according to the present invention.

Please replace the paragraph starting at page 3, line 28, with the following:

An analysis method of Borst was used to assess the performance of the prior art NACA 63<sub>2</sub>-615 airfoil and to identify the aerodynamic improvements of the invention herein[. ]; see Borst, Henry V., "A New Blade Element Method for Calculating the Performance of High and Intermediate Solidity Axial Flow Fans," NASA-CR-3063, 1979. The Borst analysis method uses a rigid-wake model in conjunction with a cascade theory to provide a blade-element analysis method able to use two-dimensional airfoil data.

$$\sigma c_l = 2 \cos(\beta_1 - \alpha_i) [\tan \beta_1 - \tan(\beta_1 - 2 \alpha_i)] K(x)/K(x)_{\text{infinity}} \quad (\text{Eq. 1})$$

In Eq. 1,  $\sigma$  is the local blade solidity;  $c_l$  is the section lift coefficient;  $\beta_1$  is the inflow angle;  $\alpha_i$  is the induced angle of attack that results from wake-induced inplane swirl;  $x$  is the non-dimensional radius; and  $K(x)$  is Theodorsen's circulation function.  $K(x)$  is a function of the number of blades, the wake advance ratio, and the radial position of the blade.  $K(x)_{\text{infinity}}$  is Theodorsen's circulation function for a fan having an infinite number of blades. The values of  $K(x)$  can be found using graphs from Borst, which were created using the rigid, helical-wake model of Gray and Wright[. ]; see Gray, Robin B., and Terry Wright, "Determination of the Design Parameters for Optimum Heavily Loaded Ducted Fans," AIAA/AHS VTOL Research, Design, and Operations Meeting, February 17-19, 1969, AIAA Paper No. 69-222; Gray, Robin B., and Terry Wright, "A Vortex Wake Model for Optimum Heavily Loaded Ducted Fans,"

Journal of Aircraft, Vol. 7, No. 2, March-April 1970. The other main equation (Eq. 2) relates the flow angle and the induced angle to an equivalent two-dimensional angle of attack.

$$\alpha = \beta_1 - \Phi - \alpha_i \quad (\text{Eq. 2})$$

In Eq. 2,  $\Phi$  is the angle between the chord line and the plane of rotation. For a given blade, the equivalent two-dimensional angle of attack can be calculated knowing the induced angle of attack.

Please replace the paragraph starting at page 5, line 18, with the following:

Figure [1] 2 is [also] a profile of the tip airfoil (20), according to the present invention, relative to the prior art NACA 63<sub>2</sub>-615 airfoil (10) shown in Figure 1. The upper surface of the tip airfoil (20) is shown at (22) and the lower surface at (23). The leading edge of the tip airfoil is at (24) and the trailing edge is at (25). The chord is shown at line (21). The tip airfoil has a thickness of 10% chord.

Please replace the paragraph starting at page 5, line 23, with the following:

The specific geometric tailoring of the tip airfoil (20) of Figure 2 [1] is given in the form of the following table of coordinates. The  $x/c$  values are dimensionless locations along the blade chord line (21). They are given for both the upper (22) and lower (23) surfaces. The  $y/c$  values are the dimensionless heights from the chord line (21) to points either on the upper or lower surface.

Please replace the paragraph starting at page 7, line 20, with the following:

Figure [1] 3 is [also] a profile of the root airfoil (30), according to the present invention, relative to the prior art NACA 63<sub>2</sub>-615 airfoil (10) shown in Figure 1. The upper surface of the root airfoil is shown at (32) and the lower surface at (33). The leading edge of the root airfoil is at (34) and the trailing edge is at (35). The root airfoil has a thickness of 14% chord.

Please replace the paragraph starting at page 7, line 24, with the following:

The specific geometric tailoring of the root airfoil (30) of Figure 3 [1] is given in the form of the following table of coordinates. The x/c values are dimensionless locations along the blade chord line (31). They are given for both the upper (32) and lower (33) surfaces. The y/c values are the dimensionless heights from the chord line (31) to points either on the upper or lower surface.

Please replace the paragraph starting at page 9, line 34, with the following:

Fan performance was calculated with the tip and the root airfoils using the baseline blade taper and twist geometry for the design thrust of 2000 LB (8900 newton). The airfoils of the invention can be used for fans having individual blades ranging from 3 to 10 meters in length. For the baseline blade the 2000 LB (8900 newton) thrust is achieved at a geometric pitch angle of 2° versus 0° for the new airfoils. For these geometric blade-pitch angles, the new airfoils result in a performance gain of 1.5% for an [the] eight-bladed 28-foot (8.534-meter) diameter fan. This gain does not take into account the gain that would be attributable to the airfoil's improved insensitivity to roughness where some measure of improvement is expected. It should be noted that the geometric pitch angle is with respect to the airfoil chord line which differs from a field pitch angle setting that is normally with respect to the lower surface of the airfoil. For the NACA 63<sub>2</sub> - 615 airfoil the field pitch setting is 4° greater than the geometric pitch angle.

**MARKED-UP VERSION OF AMENDED CLAIMS**

Please amend claims 1, 3, 4, and 6-10 as follows:

1. (amended) A family of airfoils for a blade of a cooling-tower fan, wherein the blade has a root region and a tip region, the family of airfoils comprising an airfoil in the root region of the blade having a Reynolds number of 500,000, and an airfoil in the tip region of the blade having a Reynolds number of 1,000,000, wherein the airfoil in the tip region has a maximum lift coefficient of about 1.5 and the airfoil in the root region has a maximum lift coefficient of about 1.5, and wherein each airfoil is characterized by a maximum lift coefficient that is largely insensitive to roughness effects.

3. (amended) The family of airfoils of claim [2] 1, wherein the blade has a length in a range of 3 to 10 meters.

4. (amended) The family of airfoils of claim [2] 1, wherein the tip-region airfoil has a thickness of about 10% chord and the root region airfoil has a thickness of about 14% chord.

6. (amended) The [root region] airfoil of claim 5 wherein the blade is 3 to 10 meters in length.

7. (amended) An airfoil for a blade of a cooling-tower fan wherein the blade has a root region airfoil [comprises] comprising an upper surface and a lower surface and a blade chord line wherein  $x/c$  values are dimensionless locations along the blade chord line and [the]  $y/c$  values are dimensionless heights from the chord line to points on the upper or lower surface, wherein said values correspond substantially to the following table for said surfaces:

# UPPER SURFACE

x/c	y/c
1.00000	0.00000
0.99662	0.00114
0.98703	0.00476
0.97233	0.01078
0.95346	0.01852
0.93085	0.02701
0.90436	0.03546
0.87375	0.04370
0.83919	0.05188
0.80116	0.05998
0.76012	0.06785
0.71657	0.07535
0.67101	0.08232
0.62395	0.08859
0.57590	0.09397
0.52735	0.09831
0.47876	0.10147
0.43059	0.10333
0.38330	0.10381
0.33728	0.10284
0.29293	0.10039
0.25059	0.09648
0.21061	0.09119
0.17330	0.08462
0.13897	0.07691
0.10792	0.06822
0.08040	0.05875
0.05665	0.04869
0.03685	0.03828
0.02116	0.02780
0.00968	0.01758
0.00256	0.00808
0.00019	0.00179

# LOWER SURFACE

x/c	y/c
0.00000	-0.00004
0.00021	-0.00165
0.00093	-0.00316
0.00215	-0.00470

0.00374	-0.00627
0.01354	-0.01266
0.02846	-0.01889
0.04821	-0.02465
0.07252	-0.02979
0.10113	-0.03414
0.13371	-0.03759
0.16991	-0.04003
0.20931	-0.04131
0.25153	-0.04120
0.29632	-0.03951
0.34353	-0.03619
0.39294	-0.03140
0.44418	-0.02524
0.49710	-0.01784
0.55160	-0.00978
0.60714	-0.00186
0.66285	0.00525
0.71775	0.01102
0.77079	0.01508
0.82084	0.01719
0.86679	0.01718
0.90735	0.01506
0.94113	0.01136
0.96729	0.00713
0.98565	0.00340
0.99645	0.00088
1.00000	0.00000

8. (amended) An airfoil for a blade of a cooling-tower fan wherein the blade has a tip region airfoil having a cross-sectional shape characterized by a thickness of about 10% chord and a maximum lift coefficient of about 1.5 to be substantially insensitive to roughness, and [an] a Reynolds number of 1,000,000.

9. (amended) The tip region airfoil of claim 8 [5] wherein the blade is 3 to 10 meters in length.

10. (amended) An airfoil for a blade of a cooling-tower fan wherein the blade has a tip region airfoil [comprises] comprising an upper surface and a lower surface and a blade chord line wherein  $x/c$  values are dimensionless locations along the blade chord line and [the]  $y/c$  values are dimensionless heights from the chord line to points on the upper or lower surface, wherein said values correspond substantially to the following table for said surfaces:

UPPER SURFACE

$x/c$	$y/c$
1.00000	0.00000
0.99670	0.00088
0.98716	0.00373
0.97222	0.00863
0.95269	0.01521
0.92905	0.02278
0.90137	0.03076
0.86962	0.03901
0.83410	0.04761
0.79539	0.05651
0.75405	0.06552
0.71067	0.07440
0.66582	0.08287
0.62009	0.09058
0.57397	0.09708
0.52766	0.10192
0.48128	0.10496
0.43504	0.10625
0.38928	0.10586
0.34435	0.10391
0.30064	0.10051
0.25854	0.09581
0.21849	0.08997
0.18089	0.08313
0.14614	0.07541
0.11457	0.06695
0.08648	0.05789
0.06211	0.04839
0.04163	0.03863
0.02516	0.02886
0.01280	0.01937
0.00455	0.01054
0.00047	0.00297



0.00003      0.00066

LOWER SURFACE

x/c	y/c
0.00004	-0.00070
0.00037	-0.00179
0.00120	-0.00266
0.00254	-0.00346
0.00771	-0.00536
0.02065	-0.00762
0.03926	-0.00898
0.06332	-0.00945
0.09261	-0.00909
0.12682	-0.00800
0.16562	-0.00627
0.20860	-0.00402
0.25530	-0.00138
0.30519	0.00152
0.35772	0.00455
0.41227	0.00755
0.46821	0.01041
0.52486	0.01296
0.58152	0.01510
0.63745	0.01667
0.69190	0.01759
0.74412	0.01779
0.79336	0.01725
0.83888	0.01593
0.87997	0.01390
0.91590	0.01120
0.94594	0.00809
0.96955	0.00501
0.98647	0.00240
0.99662	0.00063
1.00000	0.00000

## REMARKS

Claims 1-10 are pending in the application. Claims 1 and 9 were rejected while claims 2-4, 6-8, and 10 were objected to and claim 5 was allowed. Claims 1, 3, 4, and 6-10 are amended herein, and claim 2 is cancelled.

Applicants note that the March 22, 2002, filing date listed on the Office Action is incorrect and should be January 21, 2000. The application was originally filed as U.S. provisional patent application, S/N 60/118,985, on February 8, 1999 in the United States Patent and Trademark Office. The application was subsequently filed as a PCT application on January 21, 2000, designating the U.S. A U.S. national stage PCT filing under 35 U.S.C. 371 was performed on September 14, 2001. Due to a problem with the filing fees for the US national stage, Applicants had to petition to have the application reinstated. As a result, the filing date was incorrectly changed to March 22, 2002. Applicants respectfully request that the filing date be corrected to January 21, 2000.

The Office Action stated that the oath/declaration was defective, and required a new oath/declaration. A supplemental oath/declaration is enclosed.

The Office Action objects to Figure 1 for failing to include a "prior art" legend. A Request for Approval of Drawing Correction is included herein, along with a proposed drawing change in red ink and a revised drawing that is revised to overcome the objection.

The specification was objected to for various reasons. All objections are addressed and obviated by amendment herein.

Claim 1 was rejected under 35 U.S.C. § 102 as being anticipated by prior art Table 1, NACA 63<sub>2</sub> - 615. Claim 1 has now been amended to include the allowable subject matter of claim 2, so it should be allowable. Claim 2 is cancelled to avoid redundancy. Claims 3 and 4 are amended to depend from amended claim 1 instead of cancelled claim 2.

Claims 6-8 and 10 were objected to for various claim informalities. All objections are addressed and removed by amendment herein.

Claim 9 was rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter. Applicants submit that the grounds for objection have been removed by amendment and the amended claim 9 is now in condition for allowance.

All of the pending claims 1 and 3-10 are now believed to be in condition for allowance for the reasons explained above, and the examiner is requested to grant an early allowance. If any issues remain to be resolved, the examiner is requested to contact applicant's attorney at the telephone number listed below.

4/02/03  
Date

Respectfully submitted,

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**CERTIFICATE OF MAILING UNDER 37 C.F.R. 1.8**

I hereby certify that the foregoing Amendment and Response Under 37 C.F.R. §1.111 is being deposited with the United States Postal Service as first-class mail, postage prepaid, in an envelope addressed to: Assistant Commissioner for Patents, Washington, DC 20231, on this 2nd day of April, 2003.

Brenda E. Brantley